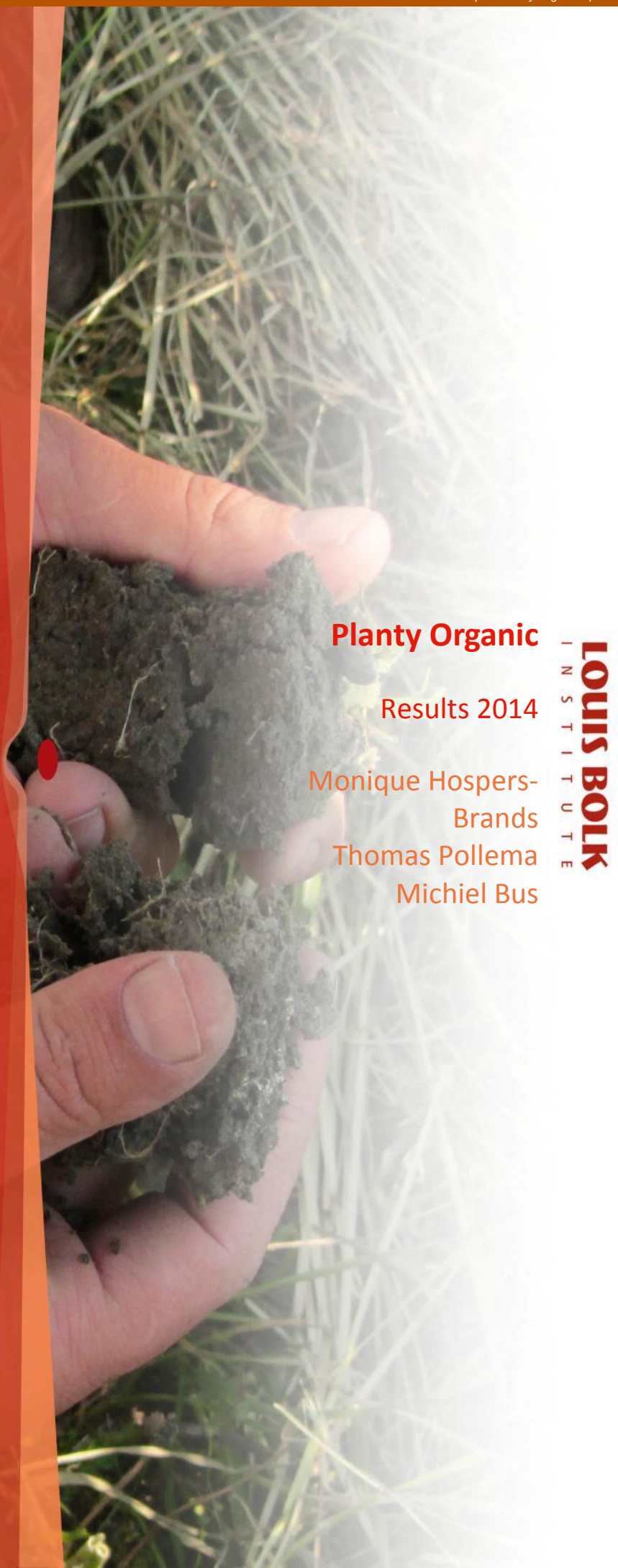


the natural source of knowledge



Planty Organic

Results 2014

Monique Hospers-
Brands
Thomas Pollema
Michiel Bus

LOUIS BOLK
I N S T I T U T E

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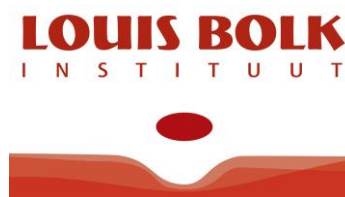
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Preface

This report is the third in a series about the development of a farming system without external input of minerals or nitrogen. The first and second report described the design of the system, and the results of the first experimental year, 2012, and the second report described the results of 2013. The report you are now reading describes the results of 2014, the third experimental year of this six-year project.

We acknowledge the members of Biowad for their input, Michiel Bus (Avestura) for organizing the project and the team of the SPNA experimental farm Kollumerwaard for their contribution in realizing this challenging experiment. We also acknowledge the institutions funding this project.



Contents

Preface	3
Contents	5
Summary	7
Samenvatting	7
1 Introduction	9
2 Experimental field	11
2.1 Weather circumstances in 2014	11
2.2 Sampling and analyses	12
2.2.1 <i>General analysis of soil fertility</i>	12
2.2.2 <i>Analyses of available nitrogen</i>	12
2.2.3 <i>Crop analyses</i>	13
2.2.4 <i>Drain water analyses</i>	14
2.3 Fertilisation	14
2.3.1 <i>Planned and realised</i>	14
2.3.2 <i>Available fertilizers December 2014</i>	15
3 Agronomy and NDICEA calculations	17
3.1 Crops	17
3.1.1 <i>Plot A Pumpkin</i>	17
3.1.2 <i>Plot B Seed Potatoes</i>	18
3.1.3 <i>Plot C Carrots</i>	19
3.1.4 <i>Plot D Rye</i>	21
3.1.5 <i>Plot E grass clover</i>	22
3.1.6 <i>Plot F Wheat</i>	23
3.2 Mineral balances	24
4 Discussion	27
5 Communication	29
Literature	31
Appendix 1 Soil fertility analyses	33
Appendix 2 Crop analyses 2014	34

Summary

2014 was the third year of the “Planty Organic” system development in practice. The six-year rotation is laid out and measurements took place at soil and crop.

The fertilizers used were completely produced in the own system, as foreseen in the system design. The nitrogen fixation by the grass clover, the motor of the system, did not meet the expected levels. The amounts of nitrogen applied were therefore about 20% lower than foreseen in the design.

Soil nitrogen is measured and used as input in the nitrogen model NDICEA. There was a sufficient match between measured and calculated level of soil mineral nitrogen, with exception of the cereals where measured values of soil mineral nitrogen were consistently lower than the calculated levels. This showed also in the field, where the cereals appeared to suffer from a lack of nitrogen, as was the case in 2013..

The wheat, rye and to a certain extent also pumpkins gave disappointing yields because of a shortage of nitrogen. Carrots and potatoes performed well.

Because of a high weed pressure no clovers were undersown in the cereals. After the harvest a leguminous green manure crop was sown. Because of wet weather circumstances in autumn no green manure crop was sown after carrots and pumpkins.

Mineral contents of the crops potatoes, carrots and wheat seem to decrease in the course of the first three years of the Planty Organic rotation. Further research into the background of this decrease is recommended.

Samenvatting

2014 was het derde jaar waarin de systeemontwikkeling “Planty Organic” in praktijk is gebracht. Op de zes percelen zijn de gewassen geteeld die voorzien waren en zijn metingen verricht aan bodem en gewas.

De gebruikte meststoffen waren geheel afkomstig vanuit het eigen systeem, zoals in het ontwerp was voorzien. De stikstofbinding door de grasklaver, de motor van het systeem, bleef achter bij de verwachtingen. Daardoor waren de totaal gegeven hoeveelheden stikstof ca. 20 % lager dan waar in het ontwerp van uit is gegaan.

De bodemstikstof is getoetst met metingen die in het stikstofmodel NDICEA zijn ingevoerd. De match tussen metingen en berekeningen is voldoende tot goed, met uitzondering van de granen, waar de metingen structureel lager waren dan de berekeningen. Dat was ook in het veld te zien. Ook in 2013 was dit het geval in de granen.

De tarwe, de rogge en in mindere mate de pompoen gewassen gaven tegenvallende opbrengsten als gevolg van stikstofgebrek. De peen en de aardappelen groeiden goed, met hoge opbrengsten. Vanwege een hoge onkruiddruk zijn geen klavers ondergezaaid inde tarwe en de rogge. Wel is hier na de oogst een vlinderbloemige groenbemester gezaaid. Na de peen en de pompoen is, vanwege de natte weersomstandigheden in het najaar, geen groenbemester gezaaid.

De mineralengehaltes van de gewassen lijken in de loop van deze eerste drie jaren van de rotatie te zijn afgenomen, met name voor fosfaat. Nader (detail)onderzoek naar de achtergrond van deze afname verdient aanbeveling.

1 Introduction

For the background of this experiment we refer to the first report on Planty Organic (Van der Burgt and Bus, 2012). Here we repeat the different aspects that are of importance for the development of this system:

- Nitrogen is brought into the farm by means of leguminous crops. Nitrogen cycling is organized partly via redistribution of above-ground leguminous biomass (cut&carry fertilizers) and partly via soil-bound transfer (in situ incorporation of leguminous biomass). Basic crop nutrient supply comes from mineralization of soil organic matter.
- There is a large stock of phosphate, potassium and other nutrients in this soil. This is explored by means of a maximum amount of catch crops in the rotation, mobilizing nutrients both out of topsoil and subsoil.
- The nitrogen moving through this agro ecological system is as much as possible organically bound. Losses of inorganic nitrogen due to leaching and denitrification are strongly reduced by minimizing the periods of bare soil and by avoiding peaks of soil mineral nitrogen.
- Soil tillage in this system has the aim to disturb soil life as least as possible. Non-inversion soil tillage maintains soil stratification, keeping intact the soil life and functionality of it.

The farm design fulfils the following objectives.

- Complete farm-own nitrogen supply by means of clover-grass, alfalfa or leguminous green manures and catch crops.
- No purchase of manure or compost
- Enough available nitrogen for a good yield and acceptable quality
- A sustainable rotation considering soil quality and nitrogen supply
- Maintenance or increase of soil organic matter content
- A for this region representative crop choice.
- During winter as much green land as possible
- Alternation of crops which are harvested above-ground (cereals, clover-grass, ...) and harvested out of the soil (potatoes, carrots, ...)

The practical realisation of Planty Organic started in 2012. In that year all crops had the same pre-crop.

In 2013 most crops had the pre-crop as foreseen in the design. Potatoes in 2013 were grown after grass clover; in future years potatoes will be grown after winter rye or oats. The plots with wheat and oats were changed in 2013, wheat was grown after cauliflower instead of after carrots, and oats was grown after carrots instead of after oats. Therefore in 2014 carrots were grown after oats instead of after wheat, and potatoes were grown after wheat instead of after oats. From 2014 onwards the cauliflower was replaced by pumpkins.

This report covers all activities of Planty Organic in 2014: the agronomical research(chapter 2, 3 and 4) , and public activities and communication (chapter 5).

2 Experimental field

2014 was the third year of this field experiment.

The field layout for 2013 and 2014 is presented in Figure 1 and Figure 2.

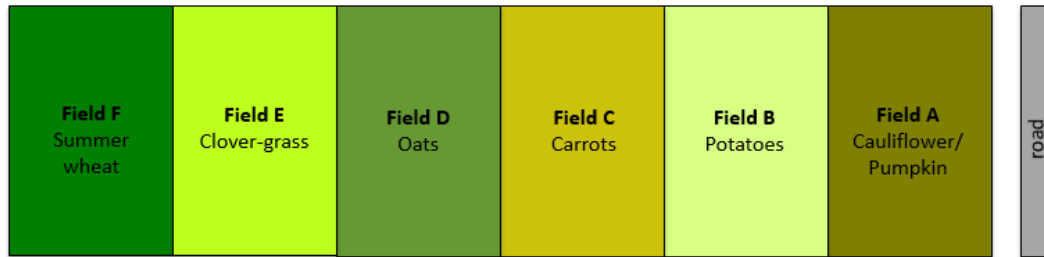


Figure 1. Field layout in 2014.

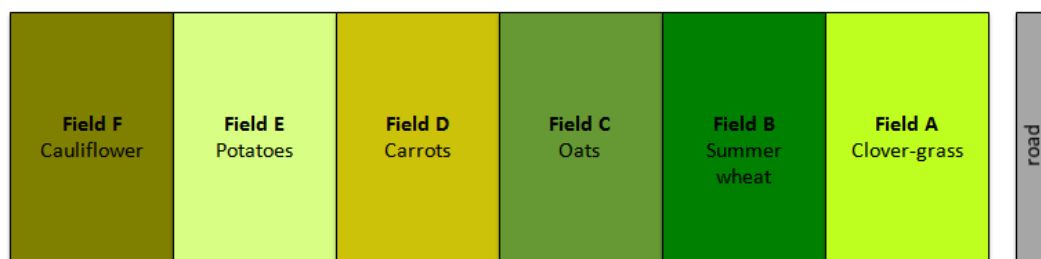


Figure 2. Field layout in 2013.

2.1 Weather circumstances in 2014

The spring in 2014 was dry (143 mm precipitation in January – April) and relatively warm (no frost, temperatures 5 – 10 °C). In May there was a lot of rain (104 mm). The summer was in the beginning dry (69 mm in June and July) and cool (temperatures not above 20 °C). August was wet (95 mm), followed by a dry and warm autumn (123 mm in September – November). December was wet again. See Figure 3.

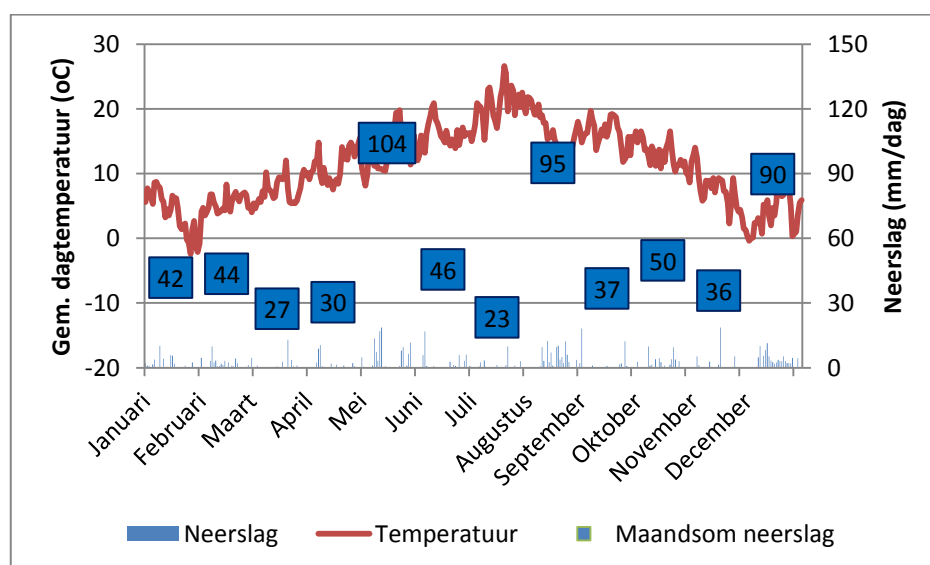


Figure 3. Temperatures and precipitation in 2014 (Weather station Munnekezijl)

2.2 Sampling and analyses

In order to be able to evaluate the performance of the system soil and crop samples were analysed.

2.2.1 General analysis of soil fertility

In November 2014 all plots were sampled for analysis of soil fertility (see appendix 1).

The results are comparable to those in 2013:

- The nitrogen supplying capacity is low.
- Phosphate and potassium are sufficiently available.
- The pH is rather high. This might limit the availability of phosphate for the crops.
- The availability of trace elements is rather low. The availability of boron and silicon is rather high.

In these first three years of the crop rotation no substantial changes in soil fertility parameters appear, see Table 1.

Table 1. Soil fertility parameters 2012 - 2014

			Plot A	Plot B	Plot C	Plot D	Plot E	Plot F
Potentially mineralizable N	kg N/year	2012	73	75	76	76	77	75
		2013	59	53	60	47	64	60
		2014	67	63	56	69	61	67
P available for plants	mg P/kg	2012	1,2	1,7	1,8	1,7	1,3	1,7
		2013	1,1	1,8	1,4	1,9	1,3	1,4
		2014	1,3	1,4	1,4	1,3	1	1,8
P-AL	mgP2O5/100g	2012	35	36	40	40	36	40
		2013	37	39	45	43	38	40
		2014	39	42	42	41	34	41
Pw	mgP2O5/l	2012	22	23	27	27	24	26
		2013	31	37	37	39	33	35
		2014	33	36	36	34	29	38
K available for plants	mg K/kg	2012	63	68	64	76	55	59
		2013	54	69	93	86	57	113
		2014	76	77	76	82	46	107
pH		2012	7,6	7,6	7,6	7,6	7,6	7,5
		2013	7,1	7,1	7,1	7,2	7,3	7,4
		2014	7,4	7,4	7,4	7,1	7,2	7,2
Organic matter	%	2012	1,6	1,6	1,8	1,8	1,8	1,8
		2013	1,8	1,9	2,1	1,9	1,9	2,1
		2014	2,4	1,9	2	2	1,8	2

2.2.2 Analyses of available nitrogen

In the design of Planty Organic the nitrogen model NDICEA was used for calculations on the nitrogen dynamics and the availability of nitrogen for the crops. The soundness of the model can be checked by analyses of the amounts of available nitrogen (nitrate) in the soil and comparison of these values with the calculations. The availability of nitrogen on all plots is measured at least three times during the growing season.

On all plots samples were taken in the layer 0-30 cm three times, and half November also in the layer 30-60 cm. In general low values were measured, see Table 2

Table 2. Soil mineral nitrogen availability in kg NO₃-N/ha

Data	depth	Plot A	Plot B	Plot C	Plot D	Plot E	Plot F
21-3-2014	0-30	0	20,3	13,1	0	0	0
5-6-2014	0-30	35,8	28,7	64,5	0	0	0
25-7-2014	0-30		32,3		11,9		17,9
3-10-2014	0-30	20,3	71,7				
13-10-2014	0-30			19,1			
21-11-2014	0-30	28,68	8,36	23,90	0	15,53	17,92
21-11-2014	30-60	23,90	35,85	28,68	0	17,92	15,53

2.2.3 Crop analyses

Besides a yield assessment on all plots all crops were analysed for dry matter contents and mineral contents (N, P, K, Mg, Ca and Na, see Appendix 2). In crop yields in 2014 are displayed, and compared to the yields as expected in the design. For rye and pumpkins the yield is lower than expected. For wheat and potato yield meet the expectations, and carrots gave a good yield, despite a lower number of plants than intended.

Table 3. Yield data (realised yield) and NDICEA standard values or expected yield in 2014.

		Yield	Dm	N-total	P ₂ O ₅	K ₂ O	N-uptake
		kg ha ⁻¹	%	% in dm	% in dm	% in dm	kg ha ⁻¹
Realised	Potato	38000	21,3	1,01	0,26	2,26	82
	Carrots	59725	10,2	1,36	0,31	3,10	83
	Pumpkin	16100	24,3	1,58	0,27	2,51	62
	Wheat	5900	89,1	1,55	0,35	0,47	81
	Rye	3300	88,0	1,32	0,41	0,55	38
Standard or expected	Potato	40000	21,0	1,57	0,59	2,72	132
	Carrots	60000	10,4	1,27	0,69	4,18	66
	Pumpkin	18000	18,3	1,90	1,10	3,10	63
	Wheat	5500	85,0	2,00	1,00	0,60	94
	Rye	4500	85,0	1,65	0,84	0,71	63

The mineral contents are all lower than the standard values NDICEA assumes. Nitrogen contents are 20 – 30 % lower (except for carrots) , as are potassium contents. Phosphate contents are even 50 – 70 % lower. In for 2012 – 2014 the relative mineral contents for potato, wheat and carrots are displayed, i.e. measured values expressed as a percentage of NDICEA standard values. In the course of years the contents of N, P and K seem to decrease, especially for phosphate. In the soil no decrease in P- and K-values is observed (see par. 2.2.1.)

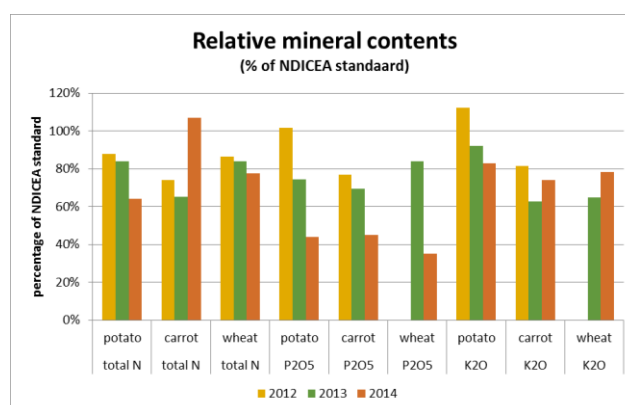


Figure 4. Relative mineral contents of products.

Grass clover was analysed after each cutting, see. Nitrogen contents were especially low in the first two cuttings, corresponding to low clover contents in spring and early summer.

Table 4. Composition of crass clover 2014.

		cutting 1 (silage) (14 May)	cutting 2 (silage) (23 June)	cutting 3 (silage) (7 August)	cutting 4 (pellets) (6 October)
Dm	%of fresh matter	42	43,7	52,1	90,2
N	g/kg dm	5,5	6,3	12,4	36,6
N-org	g/kg dm	5,1	5,7	11,4	35,2
NH4-N	g/kg dm	0,4	0,5	1	1,3
NO3-N	g/kg dm	<0,1	<0,1	<0,1	<0,1
P2O5	g/kg dm	2,8	3,3	3,1	7,8
K2O	g/kg dm	11,9	11,4	11,1	31
MgO	g/kg dm	<1,0	<1,0	2,1	5,3
CaO	g/kg dm	2,3	3,6	9,4	14,4
Na2O	g/kg dm	<0,1	<0,1	<0,1	3,4
OM	%	91	89,7	92,1	85,5
Ashes	%	9	10,3	7,9	14,5
Fresh yield	kg/ha	10945	5386	4623	2300
DM yield	kg dm/ha	4597	2354	2408	2075
N tield	kg N/ha	25	15	30	76
Totale N opbrengst	kg N/ha	146			
Totale DS opbrengst	kg ds/ha	11434			

2.2.4 Drain water analyses

Only in February and in the second half of May (after the heavy rains) the drains gave some water. The nitrate contents were low, 5 – 25 mg NO₃/l.

2.3 Fertilisation

2.3.1 Planned and realised

In the farm design it was foreseen that potatoes would receive 6,5 tonnes dm/hectare grass clover cut-and-carry fertiliser (182 kg N) and cauliflower would receive 3 tonnes dm/hectare grass clover incorporated (78 kg N), and 3,5 tonnes dm/hectare grass clover cut-and-carry fertiliser (98 kg N). The other crops would receive no fertiliser.

In 2014 the cauliflowers were replaced by pumpkins. These would receive no fertilisation but the incorporated grass clover.

In the fertilisation applied in 2014 is displayed. All fertilisation was done with fertilisers from inside the system, harvested in 2012 (grass clover silage or pellets) or in 2013 (silage). Pumpkins received only the incorporated grass clover. This was supposed to provide 300 kg/ha dry matter, and 78 kg N/ha. The grass clover was, however, lower than expected, in an amount of about 1000 kg DM/ha,

i.e. 26 kg N/ha. Potatoes received silage grass clover before planting (58 kg N/ha), grass clover pellets at planting (17 kg N/ha) and again grass clover pellets at the moment of ridge building (34 kg N/ha). In March the carrots received grass clover silage (22 kg N/ha), and the wheat grass clover pellets (86 kg N/ha). Additionally wheat received 44 kg N/ha as grass clover pellets in May.

Totally 286 kg N was given in 2014 (calculated for plots of 1 hectare). This was lower than foreseen in the design (358 kg N), mainly because of the low amount of nitrogen in the grass clover preceding the pumpkins.

Table 5. Fertilisation applied in 2014 (calculated for plots of 1 hectare).

Date	Fertilisation	Design		Applied in 2014	
		Dry matter(kg /ha)	Nitrogen (kg/ha)	Dry matter(kg /ha)	Nitrogen (kg/ha)
16-apr	Incorporated fresh matter			1000	26
	Pumpkins 2014	None	None	1000	26
11-mrt	Silage yield 2012			2502	58
14-apr	Pellets			582	17
1-mei	Pellets			1162	34
	Potatoes 2014	6500	182	4246	108
11-mrt	Silage yield 2013			1282	22
	Carrots 2014	None	None	1282	22
	Rye 2014	None	None	0	0
	Grass clover 2014	None	None	0	0
11-mrt	Pellets			2484	86
1-mei	Pellets			1511	44
	Wheat 2014	None	None	3995	130
	To be assigned	6500	176		
	TOTAL on 6 ha	13000	358	10524	286

2.3.2 Available fertilizers December 2014

In the end of 2014, 146 kg N is still available as grass clover silage or grass clover pellets from harvests in 2013 and 2014. See Table 6.

These are net amounts, to be applied on 6 plots of 0,8 ha each. Calculated for plots of 1 ha, 182 kg N is available as silage or pellets.

Table 6. Available fertilizers December 2014 (net amounts)

	Yield	Kg product	kg dm	kg N
Silage A new	2013	4750	1720	29
Silage 2014A	2014	7004,8	3678	20
Silage 2014B	2014	3447,04	1883	12
Silage 2014C	2014	2958,72	1927	24
Pellets 2014	2014	1472	1660	61
			TOTAL	146

3 Agronomy and NDICEA calculations

3.1 Crops

3.1.1 Plot A Pumpkin

Pumpkins grew after a preceding grass clover, incorporated mid-April. At this moment approximately 1000 kg/ha dry matter, 26 kg N/ha was present. The assumed amounts of 3000 kg dm/ha, 78 kg N/ha were not met. The pumpkins received no additional fertilisation.

Pumpkins were sowed in the end of May. The grass clover was not killed sufficiently, and from the end of June onwards weed control was not possible any more.

Mid-September, shortly before the harvest, the pumpkins showed somewhat less vigorous than on the adjacent field. The yield, 16 tonnes/ha, was lower than expected. The plant numbers were low and probably there was some competition of the re-growing grass clover

Nitrogen availability was good (see Figure 6), and measured soil nitrogen contents correspond quite well with the calculated amounts (see Figure 7).

Because of wet weather after the harvest no green manure was sowed after the pumpkins.



Figure 5. Crop sequence and fertilisations on plot A

1 = Oats ; 2,3,5,6,7 = Grass clover ; 4 = Potatoes, 8 = Pumpkins

A = cattle slurry, 25 tonnes ha^{-1} ; B = Monterra pellets, 500 kg ha^{-1} , 25 kg N ha^{-1} ; C = Monterra pellets, 680 kg ha^{-1} , 35 kg N ha^{-1} ; D = Cut-and-carry fertilizer grass clover, 4,4 ton dm ha^{-1} , 122 kg N-total ha^{-1} .

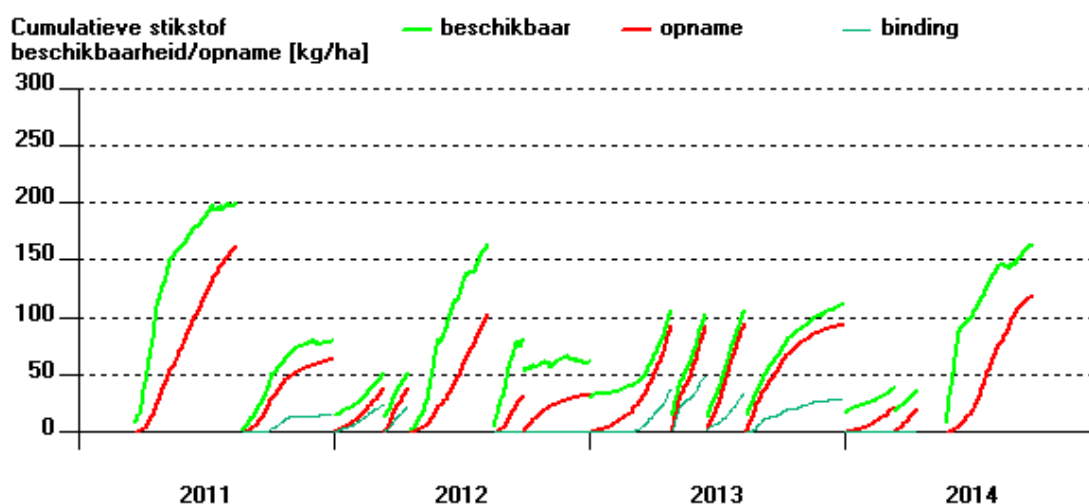


Figure 6. Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise line) on plot A, per crop. Y-axis: kg N/ha

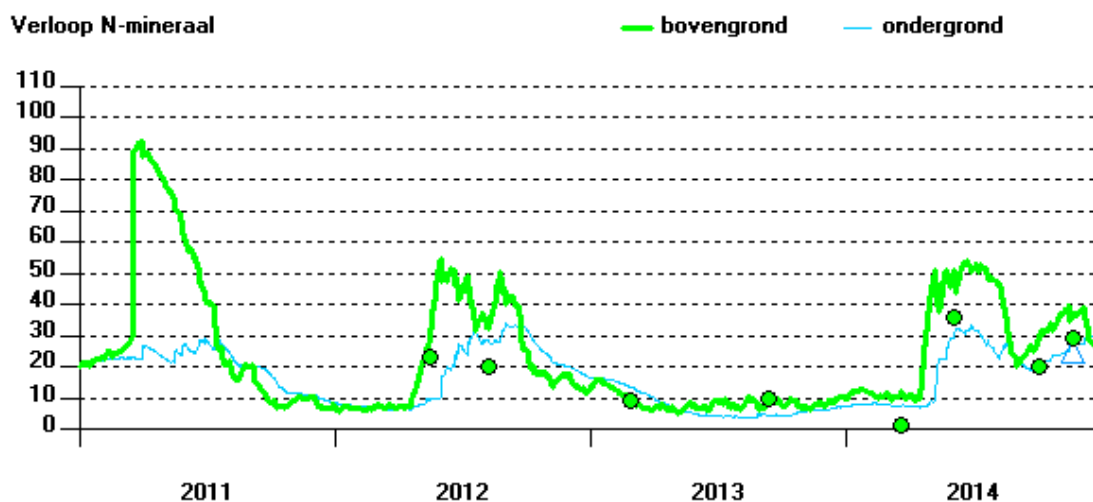


Figure 7. Course of mineral nitrogen on plot A.

Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and blue triangles: measurements in the topsoil and the subsoil. Y-axis: kg mineral N ha⁻¹.

3.1.2 Plot B Seed Potatoes

Potatoes grew after spring wheat / white clover in 2013. De aardappelen stonden na zomertarwe / witte klaver in 2013. In March grass clover silage was applied and incorporated (9600 kg/ha, 58 kg N/ha).

In July the crop shows vigorous. Copper is applied in order to prevent late blight. Mid July the foliage is destroyed, and in the end of July the potatoes are harvested. The yield was good, 38 ton/ha.

The calculated nitrogen availability was hardly enough for his yield (see Figure 9). Measures soil mineral nitrogen contents correspond quite well to the measured values (see Figure 10). Only the last measurement, in November 2014, a low value is measured, where NDICEA calculates a higher value.

After the harvest a mixture of alfalfa, white and red clover and Alexandrian clover was sown.

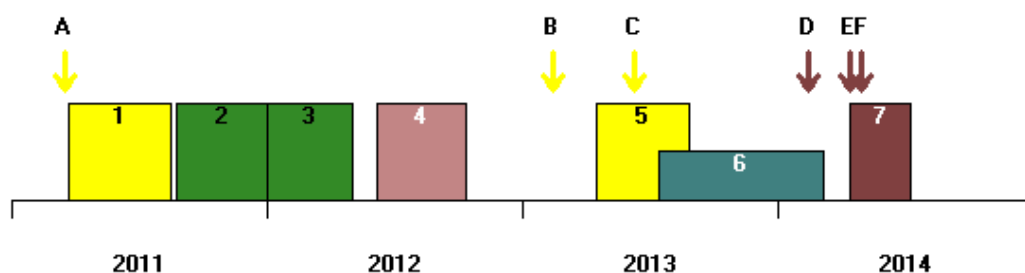


Figure 8. Crop sequence and fertilisations on plot B.

1 = Oats ; 2,3 = Grass clover ; 4 = Carrots ; 5 = Summer wheat ; 6 = White clover green manure., 7 = potato. A = Cattle slurry, 25 tonnes/ha, B = Grass clover silage, 4,2 tonnes dm/ha, C = Grass clover pellets 1200 kg/ha, D = grass clover silage, 2,5 tonnes/ha, E,f: grass clover pellets, 580 and 1160 kg dm/ha respectively.

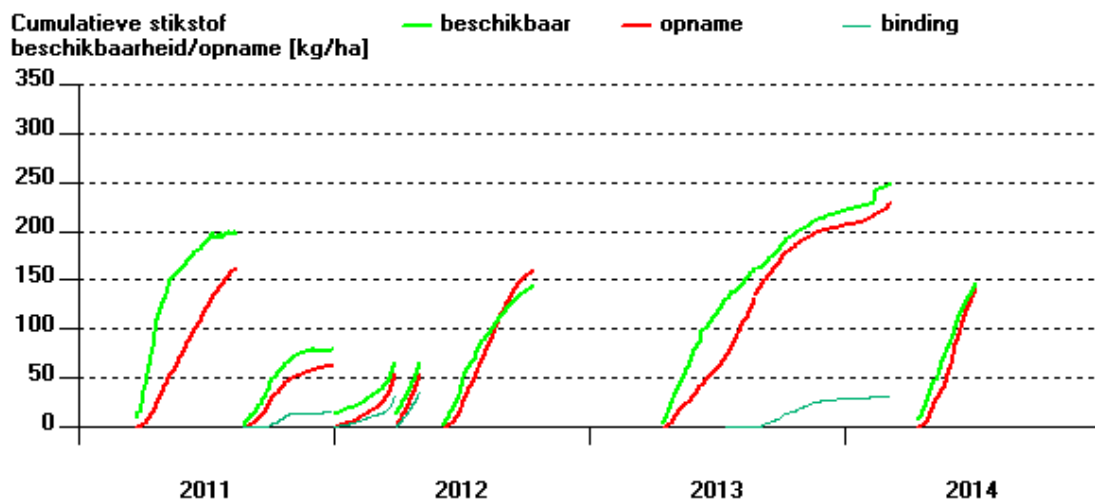


Figure 9. Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise line) on plot B, per crop. Y-axis: kg N/ha

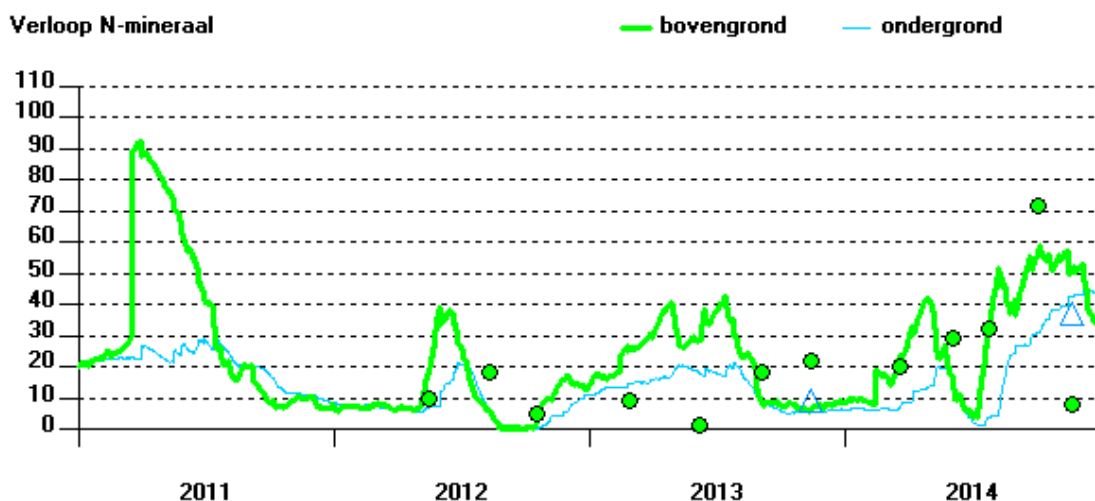


Figure 10. Course of mineral nitrogen on plot B.
Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and

3.1.3 Plot C Carrots

Carrots grow after oats with undersown red clover, incorporated mid-March 2014. At the same time grass clover silage was applied and superficially incorporated (3561 kg/ha, 22 kg N/ha). In the end of May the carrots were sown. Short after sowing a heavy rainfall resulted in a hard crust on the ridges. A far too low plant number was the result.

Weed control was successful. Mid October 60 tonnes/ha were harvested. At the background of the low plant number this was a good yield.

The calculated amounts of available soil mineral nitrogen were not too high, see Figure 9. The measured values correspond quite well to the measured amounts, see Figure 10, with the exception of one very high measurement in June.

Because of wet weather circumstances no green manure crop was sown after the harvest of the carrots.

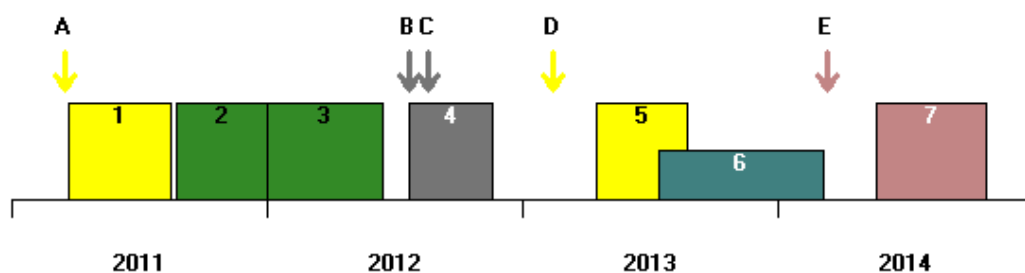


Figure 11. Crop sequence and fertilisations on plot C.

1 = oats; 2,3 = Grass clover; 4 = Cauliflower; 5 = Oats; 6 = Clover green manure; 7 = Carrots

A = Cattle slurry, 25 tonnes/ha; B = Monterra Malt pellets, 500 kg/ha, 25 kg N/ha; C = Monterra Malt pellets, 900 kg/ha, 45 kg N/ha, D = Grass clover silage, 4,2 tonnes dm/ha, E = grass clover silage, 1280 tonnes dm/ha.

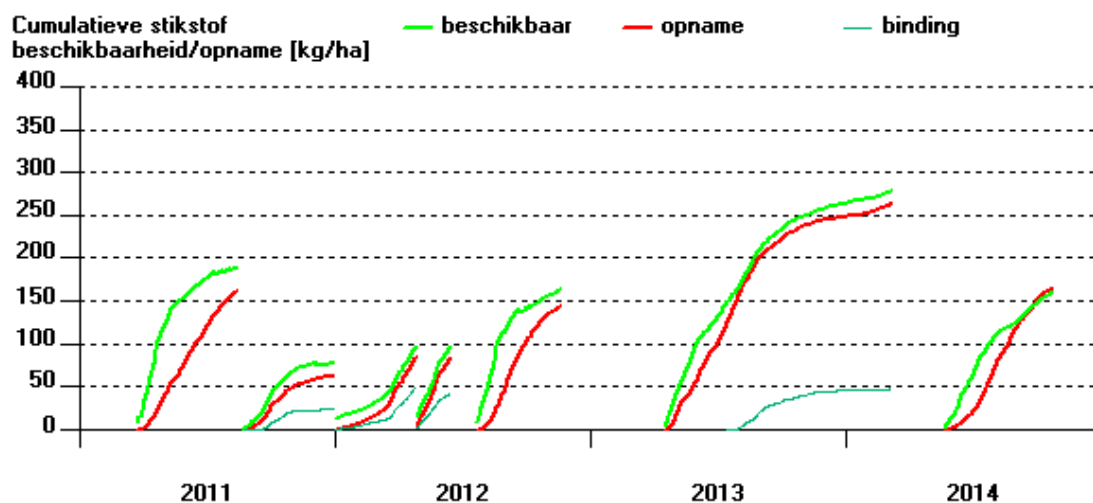


Figure 12. Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise line) on plot C, per crop. Y-axis: kg N/ha

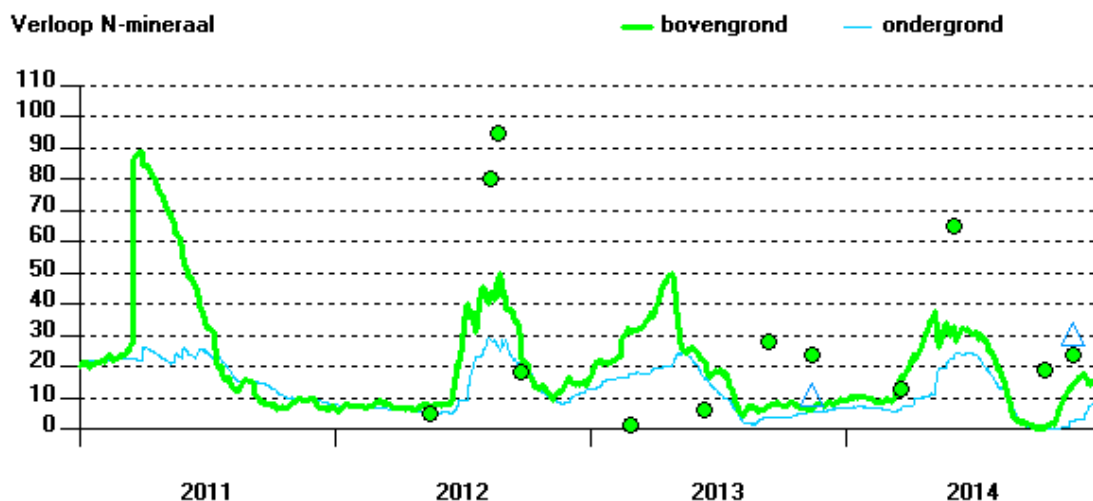


Figure 13. Course of mineral nitrogen on plot C.

Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and blue triangles: measurements in the topsoil and the subsoil. Y-axis: kg mineral N ha-1.

3.1.4 Plot D Rye

Rye grew after carrots in 2013. The winter rye was sown after the carrots as green manure crop, but grew thus well that in spring 2014 it was decided to let the rye grow further.

In summer it appeared that the nitrogen availability was too low, and a lot of weed developed.

Extra fertilisation was not available. Because of the weed no clover was undersown.

The yield, end July, was low, 3,3 tonnes/ha.

The calculated amounts of available soil mineral nitrogen was sufficient for this yield, see Figure 15.

Nevertheless the measured values were much lower than the calculated amounts, see Figure 16. It

seems that the mineralisation of soil organic matter did not start up well. In the spring of 2012 and

2013 on this plot also very low soil mineral nitrogen values were measured.

After harvest a mixture of oats and vetch was sown as a green manure.



Figure 14. Crop sequence and fertilisations on plot D.

1 = Oats ; 2,3 = Grass clover ; 4 = Spring wheat ; 5 = weeds ; 6 = White mustard ; 7 = Carrots ; 8 = Winter rye. 9 = oats/vetch green manure.

A = cattle slurry, 25 tonnes/ha ; B = Monterra pellets 1080 kg/ha, 54 kg N/ha ; C = Grass clover silage, 4,2 tonnes /ha.

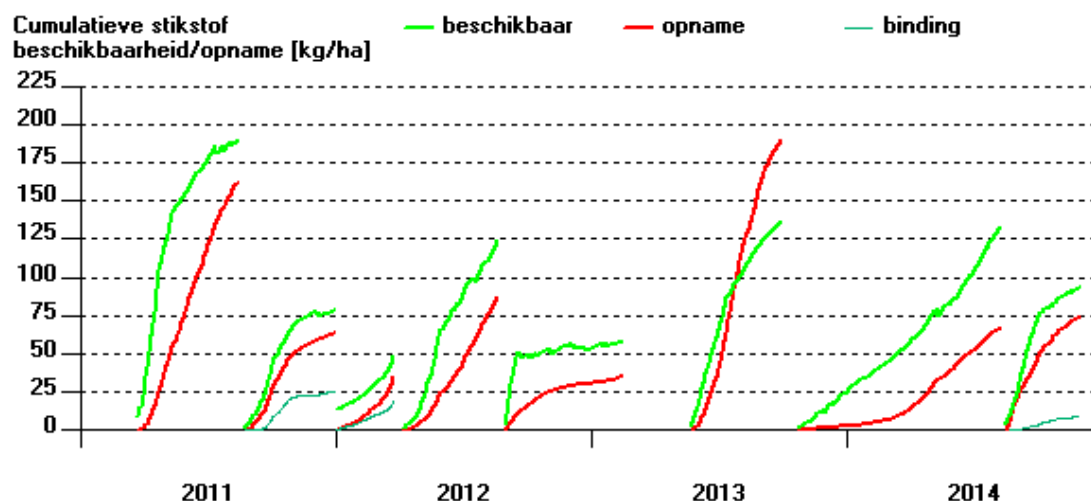


Figure 15. Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise line) on plot D, per crop. Y-axis: kg N/ha

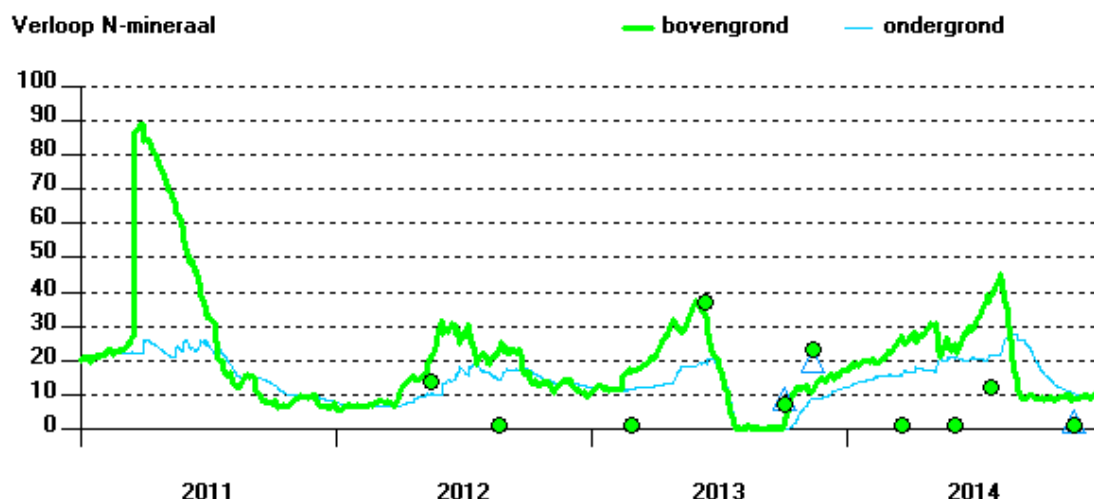


Figure 16. Course of mineral nitrogen on plot D.

Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and blue triangles: measurements in the topsoil and the subsoil. Y-axis: kg mineral N ha⁻¹.

3.1.5 Plot E grass clover

The grass clover was sown in August 2013, after the potato harvest. After the winter almost no clover remained.

Mid May the first cutting was taken, with low nitrogen contents because of the low amounts of clover. End May extra clover was sown. This was successful, resulting in higher nitrogen amounts in especially the third and fourth cutting.

The grass clover was cut four times, mid May, end July, beginning of August and beginning of October. The first three cuttings were silage, the last cutting was processed into pellets. Dry matter yields were almost 11,5 tonnes/ha. Nitrogen yields, 146 kg N/ha, were far too low, the design assumed 280 kg N/ha, see Table 4 in par. 2.2.3.

During the whole season low amounts of soil mineral nitrogen were measured. This corresponds to the calculated amounts of NDICEA, see Figure 18.

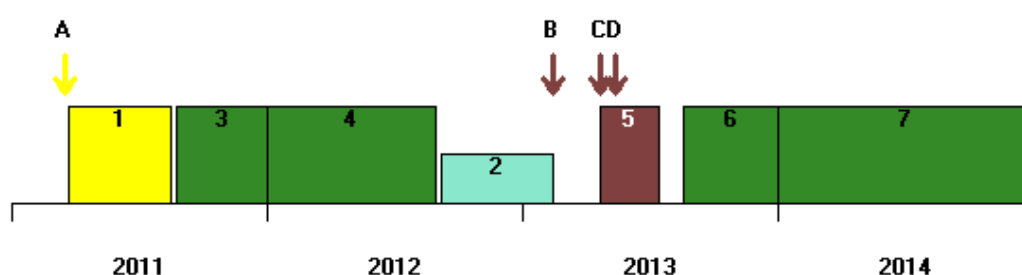


Figure 17. Crop sequence and fertilisations on plot E.

1 = Oats ; 3,4 = Grass clover ; 2 = Fodder radish ; 5 = Potato, 6,7 = Grass clover.

A = cattle slurry, 25 tonnes/ha ; B = Grass clover silage, 6,4 ton ds/ha, C = Grass clover pellets 500 kg/ha, D = Grass clover pellets, 1500 kg/ha

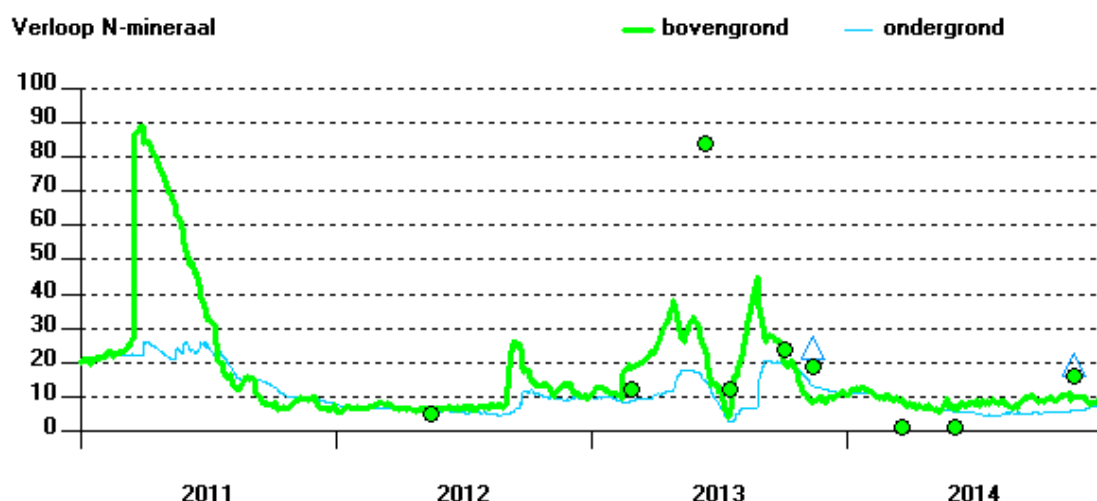


Figure 18. Course of mineral nitrogen on plot E.

Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and blue triangles: measurements in the topsoil and the subsoil. Y-axis: kg mineral N ha⁻¹.

3.1.6 Plot F Wheat

The wheat grows after cauliflowers in 2013 (not harvested, incorporated). The winter wheat was sown end October. In the end of March grass clover pellets, 86 kg N/ha) were applied and incorporated superficially. In the end of April the wheat shows too poor. Therefore in the beginning of May again grass clover pellets were applied. At this moment, the pellets applied in March were visible almost unchanged.

A heavy infestation with yellow rust, and a lot of weeds occurred. Weed control was not possible; therefore no clover was undersown. After the harvest of the wheat, end of July, a mixture of summer peas and summer vetch was sown.

According to NDICEA calculations ample amounts of nitrogen should have been available, see . The measurements, however, were much lower than the calculations, see . Enough nitrogen was applied, but for some reason this was not available for the crop.

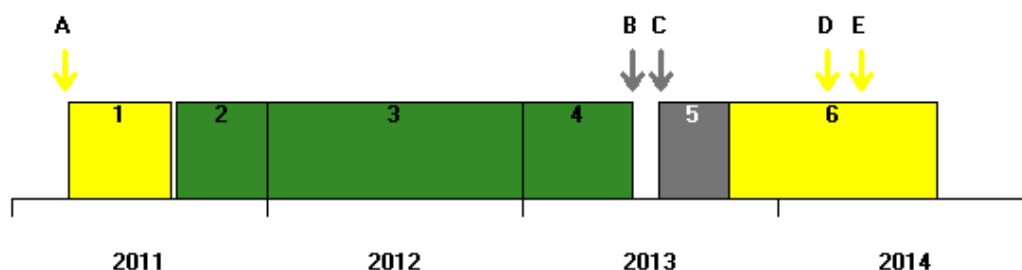


Figure 19. Crop sequence and fertilisations on plot F.

1 = Oats ; 2,3,4 = Grass clover ; 5 = Cauliflower ; 6 = Wheat.

A = Cattle slurry, 25 tonnes ha⁻¹ ; B = Grass clover cut-and-carry fertilizer, 4.3 tonnes dry matter ha⁻¹, C = grass clover pellets, 2 000 kg/ha, D, E = grass clover pellets, 86 and 44 kg N/ha respectively.

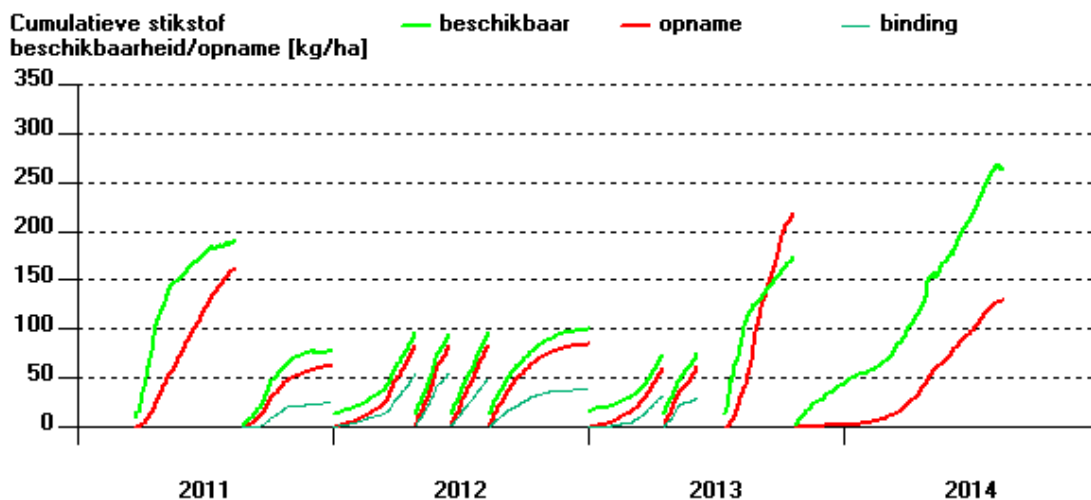


Figure 20. Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise line) on plot F, per crop. Y-axis: kg N/ha

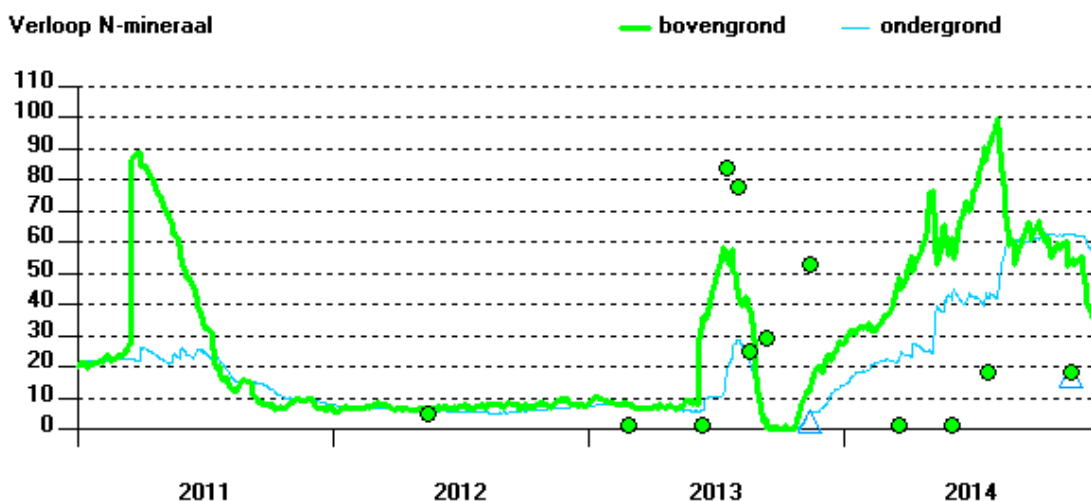


Figure 21. Course of mineral nitrogen on plot F.
Green and blue lines: calculated values for the topsoil (0-30 cm) and the subsoil (30-60 cm). Green dots and blue triangles: measurements in the the topsoil and the subsoil. Y-axis: kg mineral N ha⁻¹.

3.2 Mineral balances

In 2012 fertiliser pellets were bought for one time, because a cut-and-carry fertilizer stock was not yet build up. After that no minerals have been imported into the system (besides those in seed and planting material, and the nitrogen fixed by leguminous crops).

In Table 7 mineral balances per hectare per year are displayed, for each of the three experimental years, and for all three years together.

The balances are strongly simplified:

- Deposition is not taken into account.
- Evaporation, denitrification and leaching are not taken into account.
- Only the nitrogen in harvested cut-and-carry fertilizers is taken into account, not the nitrogen fixated by other leguminous green manure crops.

NB. In the design these factors are taken into account, but not the external input of minerals in 2012.

The nitrogen balance for nitrogen for 2012 – 2014 is slightly positive, especially as a result of the input by fertiliser pellets in the first year. In 2013 and 2014 the nitrogen balance is negative. This is not in accordance with the design, that supposed a virtually closed nitrogen balance. Especially nitrogen fixation is in practice substantially lower than in the design.

The balances for phosphate and potassium are negative, and are broadly consistent with the design.

Table 7. Mineral balances per hectare per year, in kg.

	2012			2013			2014			2012 - 2014		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Imported	31	6	31	0	0	0	0	0	0	10	2	10
N-fixation	92			46			29			55		
							Design			68		
Total inputs	122	6	31	46	0	0	29	0	0	65	2	10
							Design			68	0	0
Outflow with products	43	21	95	60	30	74	59	13	85	54	22	85
							Design			66	30	93
Balance	79	-15	-64	-14	-30	-74	-30	-13	-85	12	-20	-74
							Design			-2	-30	-93

4 Discussion

Pre-crops

In this third year of the experiment all crops had in principle the pre-crop as intended in the design. The potatoes, however, were grown after wheat (instead of after oats), and the carrots after oats (instead of wheat), because wheat and oats were exchanged in 2013.

Fertilisation

The fertilisation was with 286 kg N approximately 20% lower than foreseen (358 kg N).

Also the fixation of nitrogen by grass clover was substantially lower than foreseen: 172 kg N/ha instead of 358 kg N/ha (48%).

The grass clover on plot A, incorporated before sowing of the pumpkins, was lower, than foreseen and as a result yielded less nitrogen than foreseen. (26 kg N/ha instead of 78 kg N/ha). The grass clover on plot E had far too low clover – grass ratios in spring and in summer, and t=yielded therefore also far less nitrogen than foreseen: 146 kg N/ha instead of 280 kg N/ha.

Incorporation of grass clover pellets

The application of grass clover pellets in cereal crops remains a bottleneck: for an acceptable nitrogen utilisation the pellets have to be incorporated better than the only superficial harrowing that is possible in a growing cereal crop.

In potatoes, where the pellets are applied at the moment of planting and ridge formation this is not a problem.

Nitrogen motor

The nitrogen motor of the system is one of the six plots, on which a leguminous, nitrogen fixing crop is grown, instead of a commercial crop. This nitrogen is then by means of the harvested product, either fresh or ensilaged or dried, relocated to the other crops,

In the system design one out of six years grass clover is foreseen. This is sown after the potatoes, grows the whole year after this, and is incorporated in the next spring before the cauliflowers / pumpkins.

It appeared to be difficult to keep the clover shares on level the clover was suppressed by the grass especially in winter and spring times. As a result the nitrogen fixation was lower than expected.

Therefore in 2014 it was decided to leave the grass out of the mixture and to replace this by lucerne. The question is now if this mixture can be ensilaged well (are enough sugars available for a good acidification process?), and if the lucerne can be killed satisfactory in the next spring.

Crops

The wheat, rye and, to a lower extent pumpkins showed during the growing season signs of nitrogen deficiency. In the wheat and rye this was remarkable, because enough nitrogen was applied. The availability, however, remained poor.

Mineral contents of the crops

In the course of the first three years of Planty Organic the mineral contents of potatoes, carrots and wheat decreased every year. Especially for phosphate the decrease is substantial.

In the soil no decrease in phosphate or potassium numbers is found. The pH, however, of the soil is rather high. This might limit the availability of phosphate for the crops.

If, as a result of a low phosphate availability, root development is reduced, this might reduce the uptake of nitrogen as well.

In order to test these hypotheses further more detailed research, for example with a supplementary phosphate fertilization, would be required.

NDICEA modelling

The calculations of NDICEA are in general satisfactory consistent with the measured nitrate levels in the soil. Only in both cereal crops measured nitrate values are much lower than calculated values. For the wheat on plot F in 2014 this may be attributed to the low nitrogen availability out of grass clover pellets. The rye, however, received no fertilisation in 2014. Also in 2013 in both cereal crops measured nitrate levels were much lower than the calculated values.

A good explanation for these deviations is not yet available:

- If weather circumstances would have reduced the mineralisation from nitrogen from soil organic matter and applied fertilization, and this would have been incorporated into the model not well, the measured nitrate values in all plots would have been lower than the calculated values. This, however, is only the case in the cereal crops.
- In the nitrogen from grass clover pellets is released slower than NDICEA expects, the deviation would only occur in a cereal crop that was fertilized with grass clover pellets. In 2013, however the oats, and in 2014 the rye were not fertilized.

5 Communication

In 2014 stakeholders were informed on the development of the project. by different means:

- **Website:** On the website www.biowad.nl information on Biowad and her activities, such as Planty Organic can be found.
- **Newsletter:** In 2014 three Newsletters about Planty Organic were published, two of which were translated into English..
- **Lecture:** On 19 May prof. dr. Pablo Tittonell (professor Farming Systems Ecology at Wageningen University) gave a lecture on Kollumerwaard. Subject of the lecture was “Ecological intensification: a global perspective”.



- **Excursions:** Several groups, among which a group of Danish farmers, visited the experimental field and were informed about research on cut-and carry fertilisers, closing nutrient cycles, etcetera.

Literature

The Louis Bolk Institute performed several studies in the field of optimisation of fertilisation. Some of the reports on these studies are listed below, and can be downloaded from www.louisbolk.nl.

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- Burgt, G.J.H.M. van der, B.G.H. Timmermans, J.J.M. Staps, W. Haagsma. (2011). **Minder en Anders Bemesten: Resultaten van een vierjarig project over innovatieve bemesting**. Rapport 2010-032 LbP. Louis Bolk Instituut, Driebergen
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- Hospers-Brands, A.J.T.M., G.J.H.M. van der Burgt, J. van Strien. (2013). **Optimalisatie bemesting Van Strien: Voortgang 2012**. Rapport 2013-013 LbP. Louis Bolk Instituut, Driebergen. 27 p.
- Hospers-Brands, A.J.T.M. en J. van Strien. (2014). **Optimalisatie bemesting Van Strien: Voortgang 2013. Verschijnt maart – april 2014**. Louis Bolk Instituut, Driebergen.
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- Timmermans, B.G.H., G.H.M. van der Burgt, C. ter Berg. (2010). **Minder en Anders Bemesten Onderzoeksresultaten tuinbouw op klei. Rozendaal, kool 2010**. Rapport 2010-027LbP. Louis Bolk Instituut, Driebergen.
- Timmermans, B.G.H., G.H.M. van der Burgt, C. ter Berg.(2010). **Minder en anders bemesten: Onderzoeksresultaten tuinbouw op klei. Rozendaal, courgette 2008**. Rapport 2010-025LbP. Louis Bolk Instituut, Driebergen.
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Appendix 1 Soil fertility analyses

Yellow: lower than minimum of target value; Green: according to target values; Red: higher than maximum of target value.

		Plot A 2014	Plot B 2014	Plot C 2014	Plot D 2014	Plot E 2014	Plot F 2014	Target values min max	
N-total stock	mg N/kg	1180	1030	1040	1120	970	1110		
C/N ratio		10	9	10	9	9	9	13	17
Potentially mineralizable N	kg N/year	67	63	56	69	61	67	93	147
S-stock	mg S/kg	570	500	450	490	350	380		
C/S-ratio		21	19	22	21	26	27	50	75
Potentially mineralizable S	kg S/year	41	37	33	36	25	26	20	30
P available for plants	mg P/kg	1,3	1,4	1,4	1,3	1	1,8	1	2,4
P-stock (P-AL)	mgP2O5/100g	39	42	42	41	34	41	27	47
Pw	mgP2O5/l	33	36	36	34	29	38		
K available for plants	mg K/kg	76	77	76	82	46	107	70	110
K- stock	mmol+/kg	3,3	3,4	3,1	3,5	3	3,4	2,2	3,4
Ca available for plants	kg Ca/ha	<25	50	<26	<26	177	327	228	532
Ca- stock	kg Ca/ha	6020	5550	5225	6070	4795	5650	3830	5740
Mg available for plants	mg Mg/kg	49	48	49	51	45	48	49	82
Na available for plants	mg Na/kg	13	11	10	13	11	12	37	60
Si available for plants	μ Si/kg	43840	37080	34090	42730	42270	37780	6000	32000
Fe available for plants	μ Fe/kg	<2010	<2010	<2010	<2010	2320	<2010	2500	4500
Zn available for plants	μ Zn/kg	<100	<100	<100	<100	<100	<100		
Mn available for plants	μ Mn/kg	<250	<250	260	<250	<250	<250	1000	1300
Cu available for plants	μ Cu/kg	36	49	36	43	42	46	40	65
Co available for plants	μ Co/kg	<2,5	<2,5	<2,5	<2,5	<2,5	<2,5	25	50
B available for plants	μ B/kg	312	247	260	334	238	235	77	123
Mo available for plants	μ Mo/kg	6	12	12	11	9	12	100	5000
Se available for plants	μ Se/kg	3,6	3,7	3,5	3,7	3,4	3,4	3,5	4,5
pH		7,4	7,4	7,4	7,1	7,2	7,2	> 6,7	
C-organic	%	1,2	1	1	1,1	0,9	1		
OS	%	2,4	1,9	2	2	1,8	2		
C-anorganic	%	0,92	0,87	0,67	0,91	0,7	0,83		
Ca	%	6,9	6,5	4,9	6,8	5,1	6,1		
Lutum	%	13	10	10	12	10	11		
Silt	%	33	29	14	30	19	24		
Sand	%	45	53	69	49	64	57		
Clay-humus CEC	mmol+/kg	107	96	91	106	83	98	> 71	
CEC-occupation	%	100	100	100	100	100	100	> 95	
Soil life	mg N/kg	33	28	39	40	29	27	60	80

Appendix 2 Crop analyses 2014

	Plot	A	B	C	D	F
	Crop	Pumpkin	Seed potato	Carrot	Rye	Wheat
Yield	kg/ha	16100	38000		3300	5900
Dm	%	24,3	21,3	10,2	88	89,1
Nitrogen	g/kg ds	15,8	10,1	13,6	13,2	15,5
Phosphate	g/kg ds	2,7	2,6	3,1	4,1	3,5
Potassium	g/kg ds	25,1	22,6	31	5,5	4,7
Calcium	g/kg ds	1,1	0,71	3,2	0,47	0,33
Magnesium	g/kg ds	1,1	1,1	1,2	1	1
Sodium	g/kg ds	0,11	0,013	3,9	0,11	0,11
Sulphur	g/kg ds	1,5	1,4	1,9	1,2	1,3
Silicon	g/kg ds	0,13	<0,10	<0,10	<0,10	<0,10
Boron	mg/kg ds	18,5	7,9	28,1	4,3	4,2
Copper	mg/kg ds	4,5	6,9	7,6	4,6	4,2
Iron	mg/kg ds	39,8	56,7	36,2	29,9	27,3
Manganese	mg/kg ds	1,8	2,6	2,9	11,8	5,4
Molybdenum	mg/kg ds	1,1	1,4	0,28	1,5	1,4
Zinc	mg/kg ds	28	19,7	34,5	40	39,9